Technology Assessment Requirements for Programs and Projects

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Abstract

Program/project uncertainty can most simply be defined as the unpredictability of its outcome. As might be expected, the degree of uncertainty depends substantially on program/project type. For "hi-tech" programs/projects, uncertainty all too frequently translates into schedule slips, cost overruns and occasionally even to cancellations or failures – consummations not to be devoutly desired! Within NASA, in post mortem, the root cause of such events is often attributed to "inadequate definition of requirements." If such were indeed the "root cause," then correcting the situation would simply be a matter of requiring better requirements definition, but since history seems frequently to repeat itself, this must not be the case - at least not in total. There are in fact many contributors to schedule slips, cost overruns, project cancellations and failures, among them lack of adequate requirements definition. The case can be made, however, that many of these contributors are related to the degree of uncertainty at the outset of the project. And further, that a dominant factor in the degree of uncertainty is the maturity of the technology required to bring the project to fruition. This presentation discusses the concept of relating degrees of uncertainty to Technology Readiness Levels (TRL) and their associated "Advancement Degree of Difficulty" (AD^2) levels. It also briefly describes a quantifiable process to establish the appropriate TRL for a given technology and quantifies through the AD^2 what is required to move it from its current TRL to the desired TRL in order to reduce risk and maximize likelihood of successfully infusing the technology.

Technology Assessment Requirements for Programs and Projects

Presented By

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Technology Assessment Requirements for Programs & Projects

What is Technology Assessment?

- It is a two-step process that involves:

1. The accurate determination of the Technology Readiness Levels (TRLs) (i.e. current level of maturity).
2. The accurate determination of the Advancement Degree of Difficulty (AD^2) (i.e., what is required to advance a technology from its current TRL to what is required for infusion into the program/project at an acceptable level of risk.)

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What is Technology Assessment?

- It is a continuous, iterative process that must begin at the earliest stage of a pre-program (i.e. concept development - Pre-Phase A) and continues throughout the life of the program until final design and development begins (i.e. Phase C/D.)
- It in fact provides critical products for key decision points (KDPs), (or gates) that allow transition between program/project phases.

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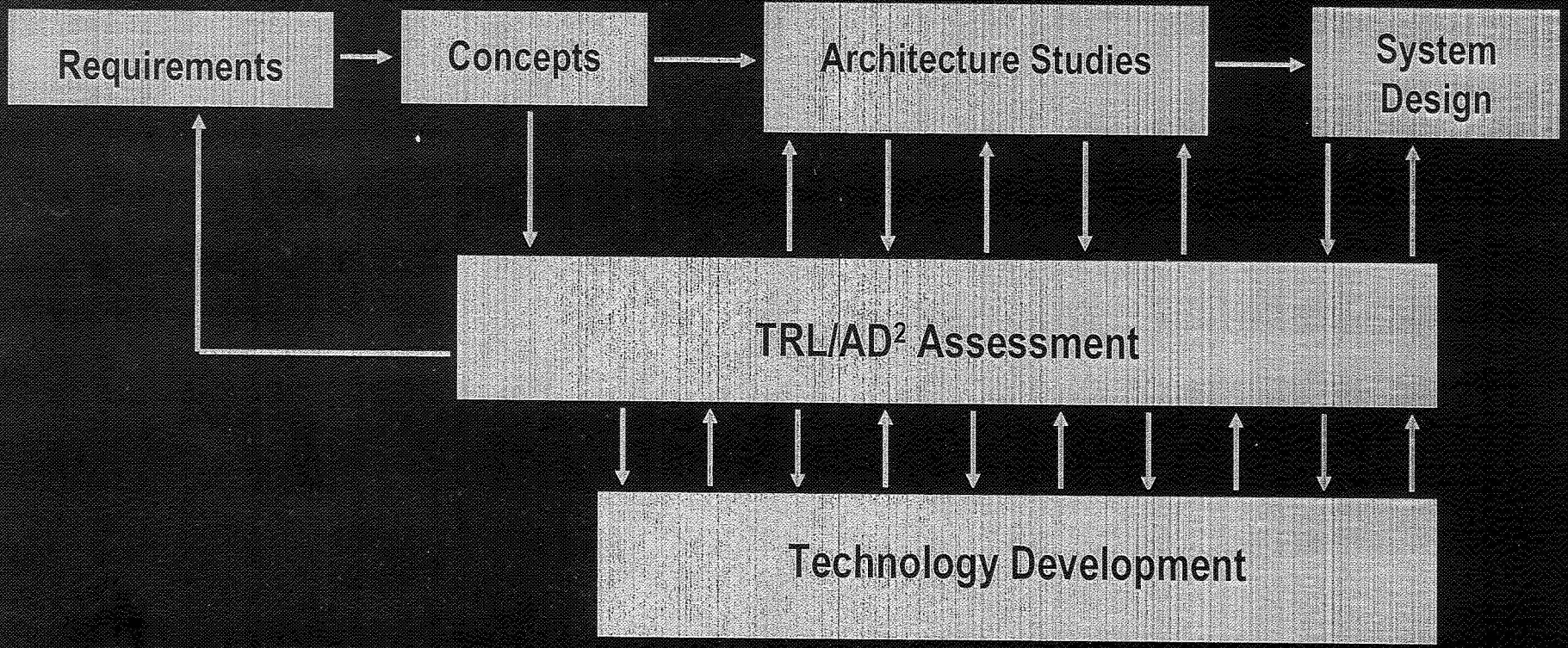
Architecture Studies And the Technology Assessment Process



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Why perform Technology Assessments?

- The Agency's programs and projects by their very nature require the development and infusion of technology in order to meet requirements.

- Failure to do this successfully is one of the major contributors to cost and schedule overruns.

- The following 4 slides are excerpts from a GAO presentation on their assessment of the reasons for cost and schedule overruns.

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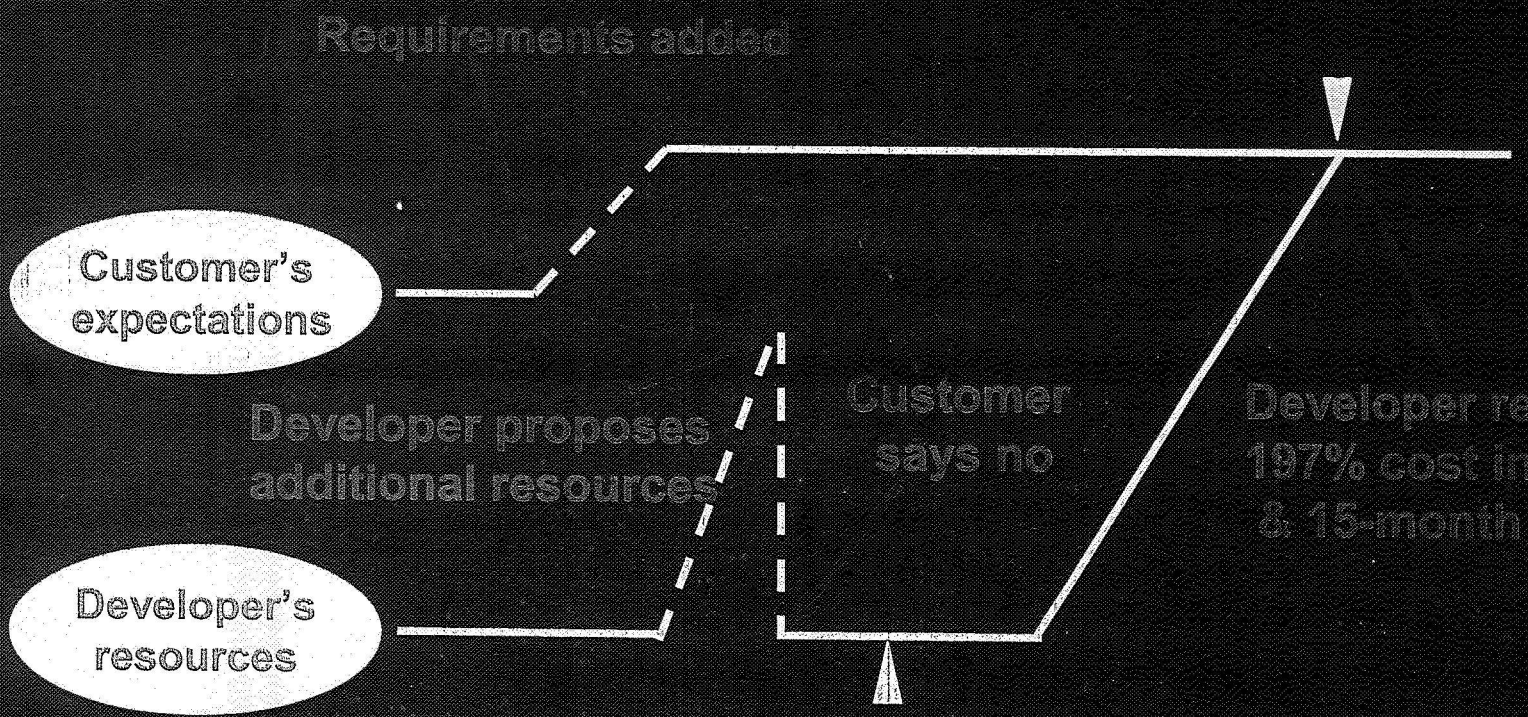
GAO Example of Requirements/Resource Mismatch & Resulting Overrun



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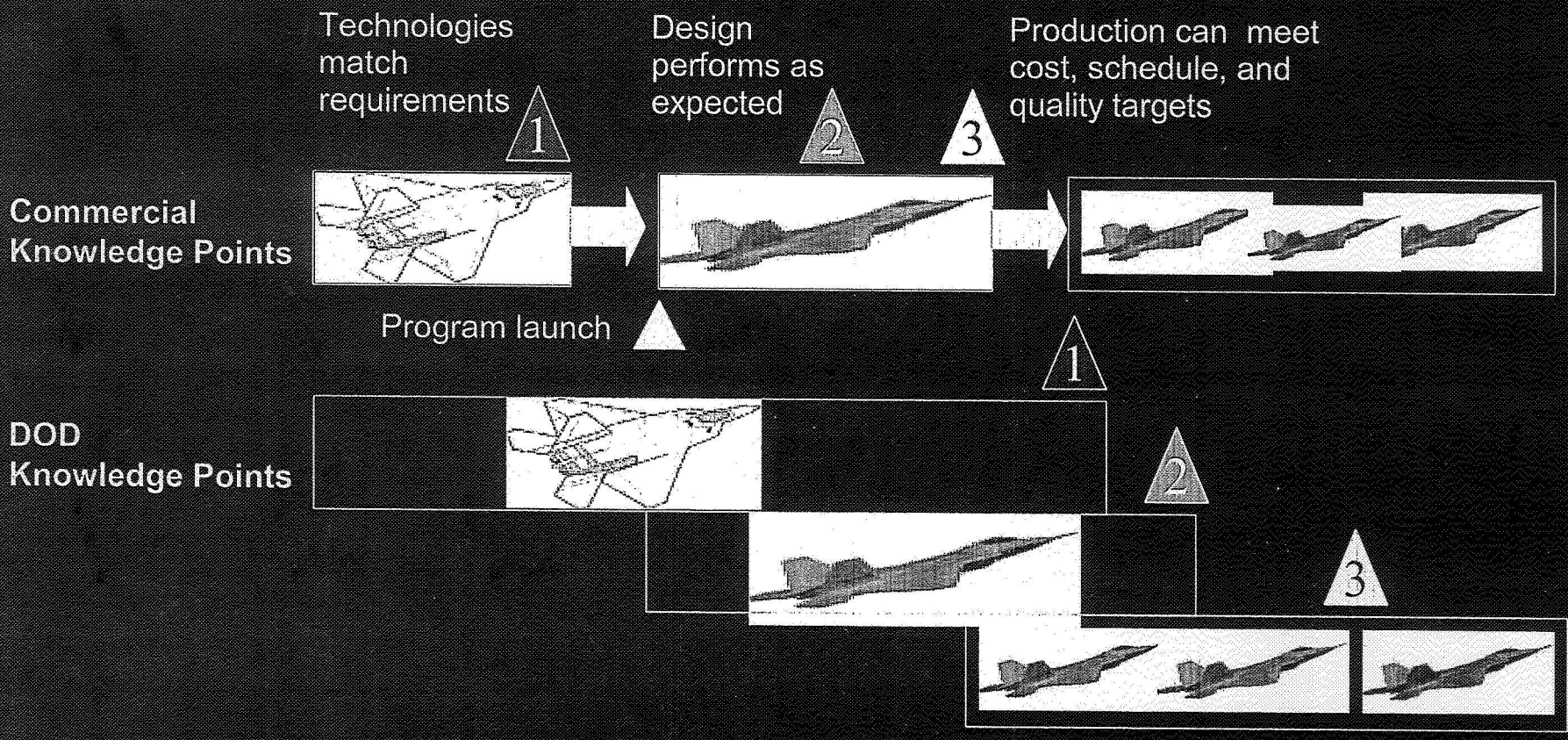
Knowledge Building for Development of New Products – GAO Study Results



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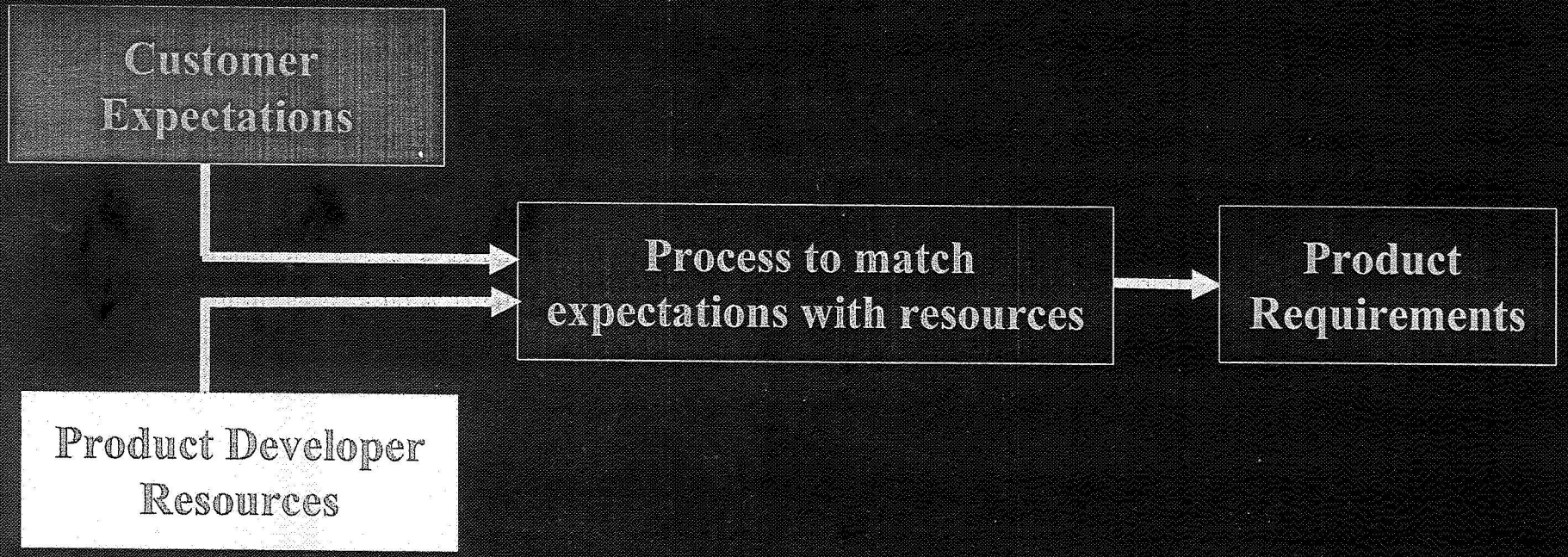
Reconciling Expectations, Resources, and Requirements – GAO Study Results



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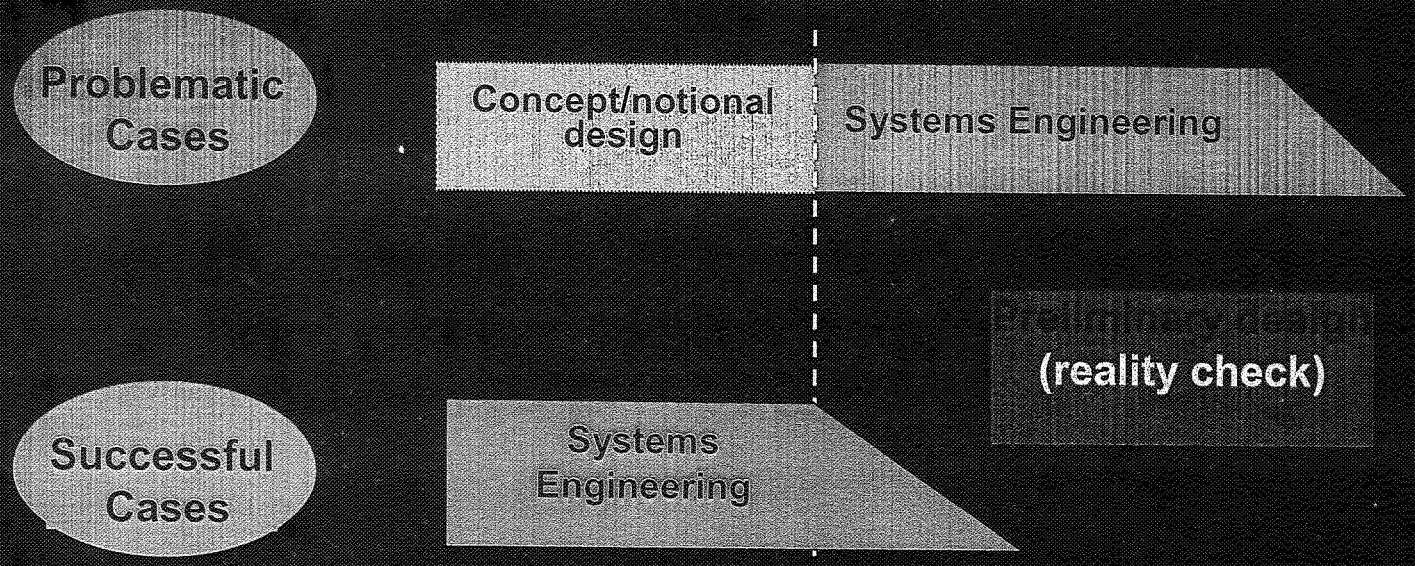
Timing of Systems Engineering – GAO Study Results



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The Assessment Process

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What is a Technology Readiness Level Assessment?

- It is the assessment of the state-of-the-art (i.e. maturity) of a given technology relative to the categories described by the Technology Readiness Levels.
- For a system, subsystem or element, the TRL for the whole is determined by the lowest TRL of its components.
- At its most basic level, the TRL is a description of what has been done at a given point in time.

NB: Operation results are critical to determining TRLs. Tests must be done in the proper environment and the unit tested must be of an appropriate scale and fidelity.

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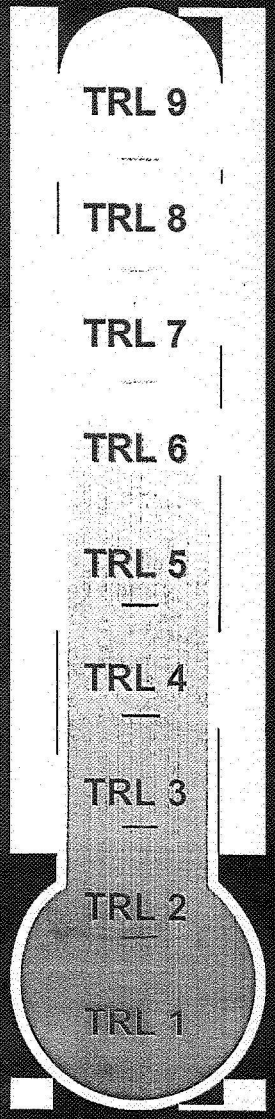

Actual system "flight proven" through successful mission operations

Actual system completed and "flight qualified" through test and demonstration (Ground or Flight)

System prototype demonstration in a space environment

System/subsystem model or prototype demonstration in a relevant environment (Ground or Space)

Component and/or breadboard validation in relevant environment

Component and/or breadboard validation in laboratory environment

Analytical and experimental critical function and/or characteristic proof-of-concept

Technology concept and/or application formulated

Basic principles observed and reported

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What is a Technology Readiness Level Assessment?

The TRL Assessment starts with a definition of the terms used in the TRL descriptions, without a common set of definitions, the assessment will be of marginal use!

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Example of Definitions

Proto-type Unit: The proto-type unit demonstrates form, fit and function. It is to every possible extent identical to flight hardware, and is built to test the manufacturing and testing processes and is intended to be tested to flight qualification levels. the only difference from the flight unit is that it is realized that elements of the proto-type unit will in all probability be changed as a result of experiences encountered in the development and testing of the Proto-type unit.

Relevant Environment: Not all systems, subsystems and/or components need to be operated in a full space/launch environment in order to satisfactorily address performance margin requirements. Consequently, the specific environment is tailored to the performance requirements being addressed.

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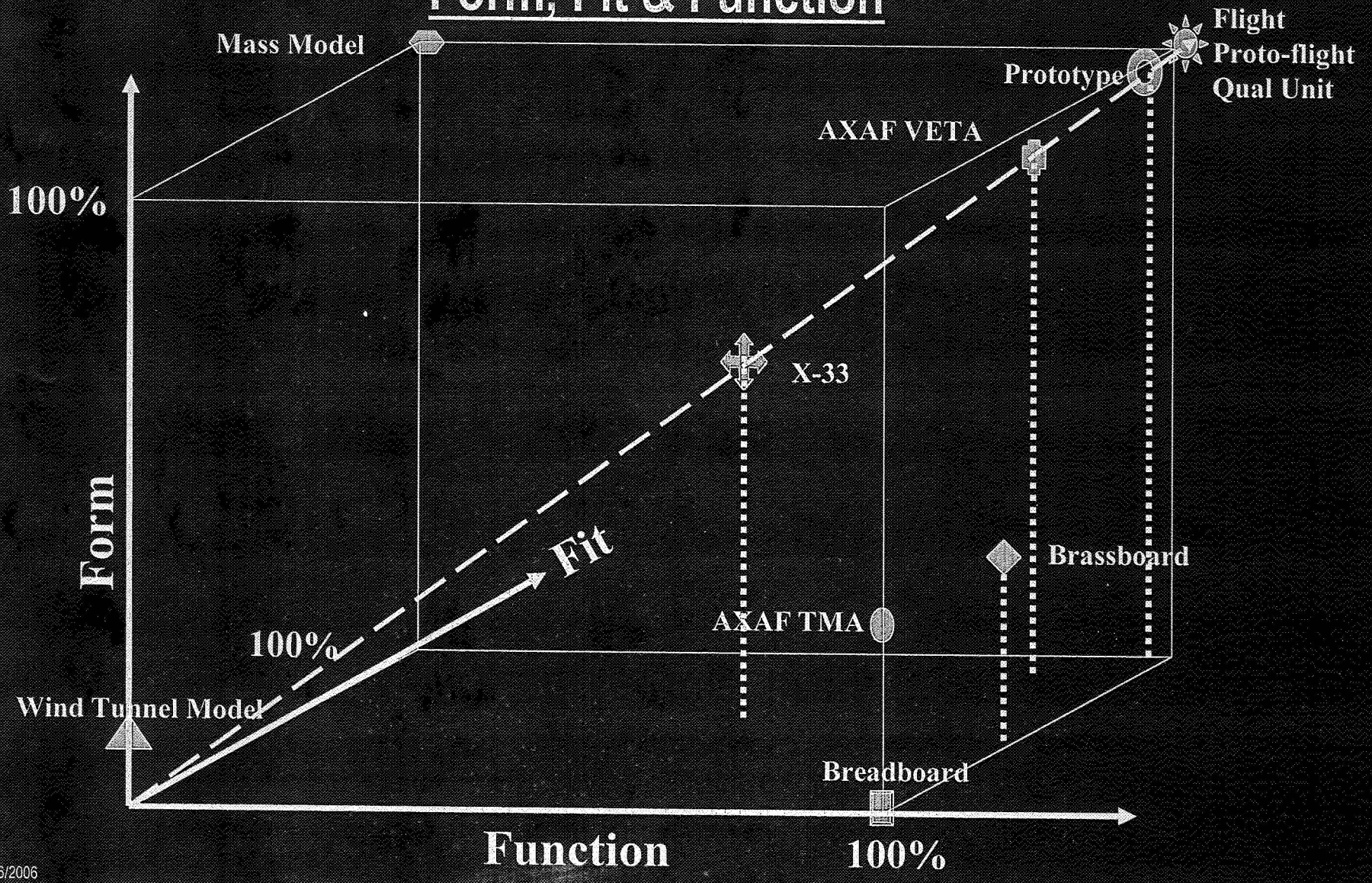
Form, Fit & Function



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Once definitions have been agreed to then a series of questions may be asked that will determine the TRL.

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TRL Assessment

Has an identical unit been successfully operated in space or launch in an identical configuration?

YES → TRL 9

NO

Has an identical unit been demonstrated in space or launch but in a different configuration and/or system?

YES → TRL 8

NO

Has an identical unit been flight qualified, but not yet flown in space or launched?

YES → TRL 8

NO

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TRL Assessment

Has a prototype unit (or one similar enough to be considered a prototype) been demonstrated in space or launch?

YES → TRL 7

NO

Has a prototype unit (or one similar enough to be considered a prototype) been demonstrated in a relevant environment e.g. thermal vac, acoustic, dynamic loads, etc.?

YES → TRL 6

NO

BEWARE - LAND OF THE UNKNOWN (THERE BE MONSTERS HERE)

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TRL Assessment

- Repeat the process for all subsystems, identifying the TRLs corresponding to each subsystem.
- Repeat the process for all elements of each subsystem, identifying the TRL corresponding to each element within a subsystem.
- The lowest TRL of the lowest element is the TRL of the system.

NB: Although TRL 6 is often referred to as the "magic" level above which there is no problem, in fact the AD^2 assessment must be done in order to quantify the cost, schedule and risk even for those technologies above TRL 6.

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TRL Assessment Matrix

	Red = Below TRL 3
	Yellow = TRL 3, 4 & 5
	Green = TRL 6 and above
	White = Unknown
X	Exists

TRL Assessment																	
		Demonstration Units						Environment				Unit Description					
	Concept	Breadboard	Brassboard	Developmental Model	Prototype	Flight Qualified	Laboratory Environment	Relevant Environment	Space Environment	Space/Launch Operation	Form	Fit	Function	Appropriate Scale	Overall TRL
1.0 System															
1.1 Subsystem X															
1.1.1 Mechanical Components															
1.1.2 Mechanical Systems															
1.1.3 Electrical Components					X				X		X	X	X		
1.1.4 Electrical Systems															

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What is an Advancement Degree of Difficulty (AD2)?

- Identifying the TRLs of the systems, subsystems and components is just one part of the equation – it establishes the baseline maturity.
- The more fundamental question is what is required (in terms of cost, schedule and risk to to advance the maturity to a level necessary for successful incorporation into the program.

- The AD^2 incorporates:
  - manufacturability (Manufacturing Readiness Levels - MRLs)
  - integration (Integration Readiness Levels - IRLs)
  - tools and capabilities (Capability Readiness Levels - CRLs)

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AD² Assessment Process

Specifically with respect to the CRL, there is an organizational aspect of technology assessment that speaks to the capability of a given organization to reproduce a technology irrespective of its maturity level. Many programs have encountered major difficulties with "heritage" technology that either could not be reproduced.

Additionally the use of "heritage" systems and components often results in important systems engineering steps being omitted under the belief that they have already been addressed – this often leads to disastrous consequences.

Technology Assessment Requirements for Programs & Projects

AD^2 Assessment Process

Overall, AD^2 assessment is one of the most challenging aspects of technology assessment. – the cost, schedule and risk associated with advancing maturity levels varies greatly with the technology.

Appropriately assessing AD^2 requires the art of "prediction," which, if it is to be accurate must rely on:

- Expert personnel
- Detailed examination of required activity.
- Review by independent advisory panel

Technology Assessment Requirements for Programs & Projects

AD^2 Assessment

Having acquired the appropriate expertise, determination of the AD^2 is primarily a matter of:

- Addressing the appropriate questions regarding the development process
- Identifying the quantitative steps in the developments that must be undertaken (breadboards, developmental models, prototypes, etc.)
- Identifying what tests must be undertaken to certify the advancement
- Making informed assessments of the degree of difficulty in pursuing the development/testing/evaluation.

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AD^2 Assessment – detailed examination of required activity

Design/Analysis:

Do you have the necessary tools for design and analysis at the level of accuracy required? If not what needs to be done, how long will it take and how difficult will it be to accomplish it?

- Data bases
- Design methods
- Analytical tools
- Models

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AD² Assessment -- detailed examination of required activity

Manufacturing:

Do you have the necessary tools/processes for manufacturing at the level of accuracy required? If not what needs to be done, how long will it take and how difficult will it be to accomplish it?

- Materials
- Metrology Process development
- Tooling
- Developmental units required

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AD^2 Assessment – detailed examination of required activity

Test & Evaluation:

Do you have the necessary equipment/processes/facilities for test and evaluation at the level of accuracy required? If not what needs to be done, how long will it take and how difficult will it be to accomplish it?

- Environmental Facilities
- Analysis Software
- Test units needed (breadboards, prototypes etc.)
- Test Hardware
- Special requirements

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AD^2 Assessment – detailed examination of required activity

Operability:

Throughout the development of the design, manufacturing and testing processes, operability must be taken into account.

- Ease of manufacture
- Operability
- Reproducibility
- Reliability
- Verifiability
- Testability
- Life cycle costs

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AD² Assessment Matrix

The answers to the questions can again be formulated into a matrix that indicates the level of risk associated with each area and provides the basis for subsequent cost and schedule estimates.

Not applicable Red = Major Concern Yellow = Moderate Concern Green = OK White = Under Evaluation Existing = 1.0 Moderate Risk = 5.0 High Risk = 8.0 Major Breakthrough = 10.0	Design & Analysis				Manufacturing									Operability							Test & Evaluation						Demonstration Units							
	Databases	Design Methods	Analytical Tools	Models	Components	Materials	Facilities	Machines	Tooling	Metrology	Mfg. Software	Mfg. Processes	Assembly & Alignment	Life Cycle Costs	Reproducibility	Manufacturability	Process Variability	Verifiability	Testability	Reliability	Integration Issues	Special Facilities	Environmental Facilities	Special Software	Special Test Equipment	Special Support Equipment	Breadboard	Brassboard	Scale Model	Engineering Unit	Prototype	Overall Numerical Score	Overall Qualitative Assessme
1.0 System																																	
1.1 Subsystem																																	
1.1.1 Components																																	
1.1.2																																	
1.1.3																																	
1.1.4																																	
1.1.5																																	
1.1.6																																	
1.1.7																																	
1.1.8																																	
1.1.9																																	
1.1.10																																	
1.1.11																																	
1.1.12																																	
1.2 Subsystem																																	
1.2.1 Components																																	

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Key Decision Points

The information contained in the TRL matrix and the corresponding AD^2 matrix provides the information required for key decision points (KDPS)

- Identifies Critical Technologies
- Provides for Information for Risk Mitigation Plan Preparation
  - Breadboards and Developmental Models Required
  - Tests Required
  - Alternate Approaches
  - Fall Back Positions and Corresponding Performance Reductions
- Overall Risk associated with technology maturity at each phase.

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Cost and Schedule

The AD^2 assessment provides considerable detail for an accurate determination of program cost and schedule.

- The identification of data bases, tools, processes, facilities tests, scale model development and integration issues in particular will assist in developing realistic cost plans.
- The identification of requirements for engineering model development and subsequent tests will be of particular benefit in outlining realistic schedules.

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Program/Project/Activity Technology Assessment Process Summary

- Clearly define all terminology used in the Technology Readiness Level (TRL) descriptions to be used throughout the life of the program/project/activity.

- Provide a formal assessment of the TRL for each system, subsystem and component as described by the program/project WBS. (The "weakest link" concept will be used in determining system and subsystem TRLs wherein the TRL of the system is determined by the subsystem having the lowest TRL in the system which in turn is determined by the component having the lowest TRL in the subsystem.

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Program/Project/Activity Technology Assessment Requirements

- On the basis of the assessment prepare a Critical Technology List, i.e., a list of those technologies that are absolutely essential in meeting requirements and that have substantial risk, cost, and/or schedule involved in the development

- Prepare a risk mitigation plan (Advancement Degree of Difficulty (AD2) for each critical technology that addresses the cost, schedule and risk associated with advancing each element to the point necessary to meet requirements in a timely manner. Identify alternative paths, decision gates, off-ramps, fallback positions, and quantifiable milestones with appropriate schedules (Technical Performance Metrics (TPM's) that measure progress towards requirements and are verified by test.

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Program/Project/Activity Technology Assessment Requirements

- Progress on risk mitigation will be tracked at periodic reviews until CDR when all appropriate risk is deemed to have been eliminated or reduced to acceptable levels.

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Summary

Successful development and incorporation of technology into programs is a hard job! But – it is not magic, it simply requires up front application of systems engineering.

It takes time and money and effort, but in the end, it must be done if the program/project is to succeed.